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Research Article

Overweight and Obesity Among Asian Indian Adults: A Systematic Review and Meta-analysis

Partha Sarathi Datta* and Rajesh Kumar Gautam

Department of Anthropology, Dr. Harisingh Gour Vishwavidyalaya (Central University), Madhya Pradesh, India

***Corresponding Author:** Partha Sarathi Datta, Department of Anthropology, Dr. Harisingh Gour Vishwavidyalaya (Central University), Madhya Pradesh, India.

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Abstract

Overweight and obesity, although a global pandemic, its prevalence varies based on environmental conditions and individual socio-economic status. At the population level, genetic make-up, geo-climatic and socio-economic conditions are regulatory factors and diet exerts control over overweight and obesity at individual level. This systematic review and meta-analysis was set out to calculate the pooled prevalence of overweight and obesity among Asian Indian adults. Based on Body Mass Index (BMI), the pooled prevalence of overweight and obesity among Asian Indian adults are 20.41% and 23.54% respectively. In this meta-analysis, 41.64% adults have had mean BMI≥23 kg/m^2, which is categorized by WHO as an overweight for Asian inhabitants. In case of habitat variation, adults from urban areas showed high prevalence for both overweight (20.15%) and obesity (34.39%) compared to their rural counterparts. Unhealthy food habits and sedentary lifestyles are main reasons of it. This systematic review and meta-analysis concluded that the prevalence rates of overweight and obesity among Indian adults of both sexes are increasing day by day. Prevention should begin at an early age, when changes in lifestyle can reduce the incidence of overweight and obesity and other associated diseases.

Keywords: Overweight and Obesity; Asian Indians; Adults; BMI; Meta-analysis

Introduction

Obesity is a new phenomenon in the history of human evolution, which was non-existent until ten thousand years ago. In the late eighteenth century, obesity was a common phenomenon among the upper classes of English people [1]. In the nineteenth century, obesity was found among North Americans and in the twentieth century, it grew in both United States of America and Britain [2]. By the year 2000, people had reached a landmark where overweight adults outnumber the adults with normal weight [3].

Overweight and obesity are defined as abnormal or excessive fat deposits that can adversely affect our health [4]. Department of Health, United Kingdom (2011) explained overweight and obesity as clinical problem. Obesity is defined on the basis of bodyweight, if a person's body weight is at least 20% higher than normal is considered as obese [5]. Primarily, Obesity was considered a medical state, not a disease; whereas in 2013, the American Heart Association (AHA) considered obesity as a disease [6].

Obesity is evolved as a measure of biological adaptation to a specific ecology, such as cold climates. Evolutionary experiences of drought after starvations play a crucial role in the process of natural selection of human by the microevolution of certain genes that enable individuals to gather and process food efficiently. In

this process, fat is stored during times of food abundance to be used during times of food scarcity (feast and famine). Such genes are known as Thrifty genes. The Thrifty Genotypic hypothesis supports the increasing prevalence of obesity [7,8].

The problem of obesity is universal, although the prevalence varies on the basis of environmental condition and socio-economic status of individual. At the population level, the genetic compositions, geo-climatic and socio-economic conditions are regulatory factors while diet regulates at individual level on overweight and obesity [7]. World Health Organization (WHO) was identified obesity as a major public health risk in 1997 and warned about the epidemic of overweight and obesity that would affect a number of countries globally [9]. Obesity has now been declared among the world's top ten health risks and is the fifth leading cause of global mortality [10]. According to the WHO, more than 1.9 billion adults are overweight or obese worldwide. Obesity has nearly tripled since 1975 globally. Countries like India, generally known for under nutrition, a significant proportion of overweight and obese people now coexist with those who are under nourished [11].

The health risks related with obesity depend on where the fat is located on the body. People with peripheral obesity where fat located at hips and thighs have lower health risks than those with central obesity in which fat is located around the stomach and gut. Obesity leads to chronic diseases such as coronary heart disease, diabetes, high blood pressure, stroke, osteoporosis etc. [12]. In addition obesity increases the risk of several cancers (including endometrial, breast, ovarian, prostate, liver, gallbladder, kidney, and colon) [10]. Approximately thirty thousand annual global deaths are currently caused by obesity and with the increasing prevalence it is estimated that obesity will overtake smoking tobacco as the leading cause of premature death by the year 2030 [13].

According to WHO-Global Health Observatory data 2016, the global prevalence of adult with BMI≥25 kg/m^2 was 38.9%, where 38.5% and 39.2% of adult males and females have had BMI≥25 kg/m^2 respectively. Among WHO regions, Americans showed the maximum value of adult's BMI (≥25 kg/m^2) of 62.5%, where South-East Asians showed the least value of adult's BMI (≥25 kg/m^2) of 21.9% in 2016 [14]. Among South Asian countries, in Bhutan, the maximum value of adult's BMI (≥25 kg/m^2) were 44.9% in 2019, whereas India has lowest prevalence (24.2%) of adults with BMI (≥25 kg/m^2) in 2019-20. Bhutan showed the maximum percentage of male and female overweight/obesity of 40.1% and 50.3% respectively. Bangladesh has low prevalence of male overweight/obesity (18.3%) whereas India has low prevalence of female overweight/obesity (23.5%) among the adults [15]. In India, according to National Health and Family Survey (NFHS-5), the prevalence of overweight/obesity is doubled in past 15 years. It was merely 9.3% and 12.6% among adult males and females during 2005-06 but in recent survey it was reported 22.9% for adult males and 24% for adult females in 2019-21 [16].

As obesity is a global pandemic, it is widely studied around the globe. It is also studied Asian Indians but there is gap of knowledge about the trend of studies hence this systematic review and meta-analysis was planned with the objectives (i) to find out the pooled prevalence of overweight and obesity among adult Asian Indians (ii) to find out the ethnic and regional variation in the prevalence of overweight and obesity and (iii) to find out the sex wise pooled prevalence of overweight and obesity on the basis of Body Mass Index (BMI) and Waist Circumference (WC).

Methods

Criteria for inclusion and exclusion

There were three main inclusion criteria: (i) full text cross-sectional studies published in peer reviewed journals (ii) studies published in English language between January 2000 to June 2022 and (iii) studies reporting the prevalence of overweight or/and obesity among Asian Indian adults based on BMI or/and WC. Out of 92, 51 studies were excluded as they were review studies, non cross-sectional method, reporting of miscalculations and unavailability of full text.

Search strategy

At first, the PROSPERO (Prospective Register of Systematic Reviews) databases were examined whether a systematic review and meta-analysis existed or whether there were ongoing projects related to overweight and obesity among Indians. This systematic review and meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines [17]. Articles were searched from electronic databases as PubMed, PubMed Central,

Google Scholar and Scopus, using the following terms or MeSH – 'overweight', 'obesity', 'Asian Indian adults' and 'Prevalence'. The key terms or MeSH were combined with Boolean Operators like 'of', 'and' and 'among'.

Search	Search Terms (Boolean Operators)
1	'Prevalence' 'of' 'overweight' 'among' 'Asian Indian adults'
2	'Prevalence' 'of' 'obesity' 'among' 'Asian Indian adults'
3	'Prevalence' 'of' 'overweight' 'AND' 'obesity' 'among' 'Asian Indian adults'

Table 1: Key terms and Boolean Operators used for search.

The PRISMA diagram (Figure 1) illustrates the selection process and shows the reasons for exclusion. Out of 92, 41 full-text articles were selected for this systematic review and meta-analysis which reported necessary statistics on overweight and obesity among adults of Asian Indian origin.

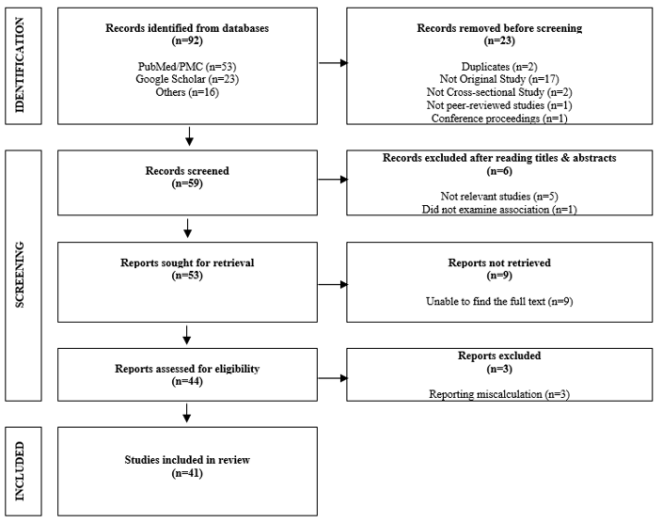

Figure 1: PRISMA diagram showing study selection for the prevalence of overweight and obesity among Asian Indian adults.

Data extraction

All the necessary data includes name of the first author, year of publication, name of the journal, study type, area of the study, age and sex of the participants, sample size, mean and SD of BMI and WC, prevalence of overweight or/and obesity according to BMI, both WHO Asian and International cut offs were extracted using a Excel worksheet. The extracted data of BMI were categorized based on the WHO classification of BMI for Asians-Overweight if the BMI is ≥23 kg/m^2 and Obese if it is ≥25 kg/m^2 for the study participants included in this systematic review and meta-analysis.

Statistical analysis and publication bias

The descriptive statistics, like combined mean and SD of BMI and WC were calculated using MS-Excel software. Meta analysis was performed by MedCalc Software (Version 20) using the fixed and random effect model to find out the pooled prevalence of overweight and obesity of selected studies. The data of prevalence was mentioned with 95% confidence interval and weight, both in fixed and random effects in percentage [18].Heterogeneity is defined as dissimilarity between elements that comprise the whole. The most commonly used heterogeneity measure, I^2 statistic, describes the percentage of diversity throughout the studies which is due to heterogeneity rather than chance [19]. Publication bias was calculated by Funnel plot and the Egger's test, which was performed to describe the asymmetry of the distribution of selected studies [20]. Forest plot, display the effect estimates on the horizontal scale, and thus the measure of study size on the vertical axis. Meta-regression analysis was performed to explore the heterogeneity between the studies reporting prevalence of obesity [18]. Residual SD and F-test were also calculated in meta-regression.

Results

Variability of BMI

In this current meta-analysis, out of 41 studies, 27 studies were included to estimate the mean BMI among Indian adults. Variability of BMI (mean ± SD) among Asian Indian adults reported from 2001 to 2022 is displayed in table 2.

The total sample size of selected studies was 39,704 which constitute 23,821 males and 15,883 females. The combined mean of BMI for males and females were 20.31 ± 3.77 kg/m^2 and 22.67 ± 4.71 kg/m^2 respectively. It is evident from table-2, that highest mean BMI was reported by Vijayanchali (2014) [38] from Dindigul, Tamil Nadu. The reported mean BMI for male was 27.8 ± 4.9 kg/m^2

SL	Name of the Study	Area of the Study	Male			Female		
			n	Mean BMI (kg/m^2)	SD	n	Mean BMI (kg/m^2)	SD
1	Misra., *et al*. 2001[21]	South Delhi, Delhi	165	20.0	4.1	359	20.7	4.5
2	Adak., *et al*. 2006 [22]	MP and Chhattisgarh	11496	18.43	2.18			
3	Misra., *et al*. 2006 [23]	New Delhi	883	22.8	5.2	1176	23.0	5.7
4	Chhabra., *et al*. 2007 [24]	Delhi	1360	21.65	4.09	2068	22.46	4.89
5	Masoodi., *et al*. 2009 [25]	Jammu and Kashmir	2119	21.11	2.45	905	21.18	2.03
6	Deepa., *et al*. 2009 [26]	Chennai	1096	22.6	3.8	1254	23.1	4.1
7	Mungreiphy., *et al*. 2010 [27]	Ukhrul, Manipur				346	21.23	2.78
8	Mungreiphy., *et al*. 2011[28]	Ukhrul, Manipur	257	20.9	2.39			
9	Misra., *et al*. 2011[29]	Ballabgarh, Haryana				307	22.16	4.32
10	Bhardwaj., *et al*. 2011[30]	New Delhi	217	24.8	4.1	242	25.0	4.9
11	Sudhera., *et al*. 2012 [31]	Amritsar, Punjab				150	21.35	3.4
12	Sen., *et al*. 2013 [32]	Jalpaiguri, West Bengal	300	21.5	2.82	300	23.19	3.28
13	Kaur., *et al*. 2013 [33]	Punjab				300	26.92	5.03
						300	25.46	4.7
14	Kaur., *et al*. 2013 [34]	Amritsar, Punjab	200	26.72	1.57	200	27.12	1.85
15	Sindhu, 2013 [35]	Haryana	649	21.24	4.06	833	20.72	4.09
16	Rao., *et al*. 2013 [36]	Pune, Maharashtra	210	25.6	3.1	209	26.5	3.8
17	Rathi., *et al*. 2014 [37]	Pune, Maharashtra				1063	23.01	1.14
18	Vijayanchali , 2014 [38]	Dindigul, Tamil Nadu	160	27.8	4.9	214	29.7	5.2
19	Aswathappa., *et al*. 2014 [39]	Kolar, Karnataka	840	24.84	4.4	511	25.38	4.89
20	Midha., *et al*. 2014 [40]	Kanpur, Uttar Pradesh	356	21.4	3.9	445	22.4	4.6
21	Rengma., *et al*. 2015 [41]	Karbi-Anglong, Assam	422	22.66	2.07	404	22.3	2.43
22	Kshatriya., *et al*. 2016 [42]	West Bengal, Odisha, Gujarat	1066	20.0	2.9	1090	19.2	3.1
23	Lin., *et al*. 2018 [43]	Ladakh	47	24.9	4.0	102	26.4	4.3
24	Tigga., *et al*. 2018 [44]	Uttar Dinajpur, West Bengal	182	21.18	3.3	238	20.89	3.47
25	Devi., *et al*. 2019 [45]	Delhi	184	26.29	4.78	234	28.01	5.54
26	Ganie., *et al*. 2021 [46]	Kashmir, Jammu and Kashmir	1612	21.34	4.15	2426	22.26	5.08
27	Thanglen., *et al*. 2022 [47]	Manipur				207	23.2	4.04
Combined Mean Combined SD		TOTAL	23821			15883		
			20.31			22.67		
				3.77			4.71	

Table 2: Variability of BMI (Mean ± SD) among Asian Indian adults.

and for female was 29.7 ± 5.2 kg/m^2. Similarly lowest mean BMI for male was 20.0 ± 4.1 kg/m^2, reported by Misra., *et al*. (2001) [21] from South Delhi, and for female was 19.2 ± 3.1 kg/m^2, reported by Kshatriya and Acharya (2016) [42] from three Indian states, West Bengal, Odisha and Gujarat.

Variability of BMI on the basis of <23 kg/m^2 and ≥23 kg/m^2 among Asian Indian adults of 19 studies are mentioned in Table 3. The total sample size of selected studies is 15941. Among total samples, 9303 participants had BMI<23 kg/m^2 (58.36%) and 6638 participants had BMI≥23 kg/m^2 (41.64%). Here, Mungreiphy., *et al*. (2011) [28] showed highest percentage of BMI<23 kg/m^2 (82.49%) from Ukhrul, Manipur and Sawant., *et al*. (2011) [48] showed the highest percentage of BMI≥23 kg/m^2 (79.02%) from Mumbai, Maharashtra.

SL	Name of the Study	Area of the Study	n	BMI (kg/m^2)			
				<23	%	≥23	%
1	Mungreiphy., *et al*. 2010 [27]	Ukhrul, Manipur	346	252	72.83	94	27.17
2	Mungreiphy., *et al*. 2011 [28]	Ukhrul, Manipur	257	212	82.49	45	17.51
3	Bhardwaj., *et al*. 2011 [30]	New Delhi	459	153	33.33	306	66.67
4	Sawant., *et al*. 2011 [48]	Mumbai, Maharashtra	548	115	20.98	433	79.02
5	Sudhera., *et al*. 2012 [31]	Amritsar, Punjab	150	104	69.33	46	30.67
6	Sen., *et al*. 2013 [32]	Jalpaiguri, West Bengal	600	351	58.50	249	41.50
7	Manjunath., *et al*. 2014 [49]	Hyderabad, Andhra Pradesh	473	308	65.11	165	34.89
8	Vijayanchali , 2014 [38]	Dindigul, Tamil Nadu	2977	2100	70.54	877	29.46
9	Rengma., *et al*. 2015 [41]	Karbi-Anglong, Assam	826	468	56.65	358	43.35
10	Sharma., *et al*. 2016 [50]	Chandigarh	350	80	22.85	270	77.15
11	Kumar., *et al*. 2016 [51]	Rachi, Jharkhand	500	308	61.60	192	38.40
12	Nagendra., *et al*. 2017 [52]	Shivamogga, Karnataka	2000	1086	54.30	914	45.70
13	Karmakar., *et al*. 2018 [53]	Hooghly, West Bengal	510	241	47.25	269	52.75
14	Shikha., *et al*. 2019 [54]	Dehradun, Uttarakhand	632	320	50.63	312	49.37
15	Manojan., *et al*. 2019 [55]	Trivandrum, Kerala	350	174	49.71	176	50.29
16	Bindhu., *et al*. 2019 [56]	Trivandrum, Kerala	300	106	35.33	194	64.67
17	Devi., *et al*. 2019 [45]	Delhi	418	136	32.53	282	67.47
18	Ganie., *et al*. 2021 [46]	Kashmir, Jammu and Kashmir	4038	2675	66.24	1363	33.76
19	Thanglen., *et al*. 2022 [47]	Manipur	207	114	55.07	93	44.93
		TOTAL	15941	9303	58.36	6638	41.64
[BMI<23 kg/m^2: Underweight + Normal / BMI≥23 kg/m^2: Overweight + Obese)]							

Table 3: Variability of BMI (<23 kg/m^2 and ≥23 kg/m^2) among Asian Indian adults [According to WHO BMI Cut off (Asian)] [Arranged by year of publication].

In 23 studies, the variability of BMI<25 kg/m^2 and ≥25 kg/m^2 are discussed as displayed in Table 4. The total sample size of selected studies was 20726. Among total samples, 15855 participants had BMI<25 kg/m^2 (76.49%) and 4871 participants had BMI≥25 kg/m^2 (23.51%). Here, Mungreiphy., *et al*. (2011) [28] showed highest percentage of BMI<25 kg/m^2 (98.44%) from Ukhrul, Manipur and Sharma., *et al*. (2016) [50] showed the highest percentage of BMI≥25 kg/m^2 (58.58%) from Chandigarh.

SL	Name of the Study	Area of the Study	n	BMI (kg/m^2)			
				<25	%	≥25	%
1	Sidhu., *et al*. 2002 [57]	Amritsar and Ludhiana, Punjab	1000	547	54.70	453	45.30
2	Mungreiphy., *et al*. 2010 [27]	Ukhrul, Manipur	346	339	97.97	7	2.03
3	Mungreiphy., *et al*. 2011 [28]	Ukhrul, Manipur	257	253	98.44	4	1.56
4	Bhardwaj., *et al*. 2011 [30]	New Delhi	459	229	49.89	230	50.11
5	Sawant., *et al*. 2011 [48]	Mumbai, Maharashtra	548	363	66.24	185	33.76
6	Rao., *et al*. 2011 [58]	Karnataka	1239	892	71.99	347	28.01
7	Sudhera., *et al*. 2012 [31]	Amritsar, Punjab	150	134	89.33	16	10.67
8	Sen., *et al*. 2013 [32]	Jalpaiguri, West Bengal	600	483	80.50	117	19.50
9	Sindhu, 2013 [35]	Haryana	1482	1256	84.75	226	15.25
10	Dua., *et al*. 2014 [59]	Delhi	240	144	60.00	96	40.00
11	Kumar., *et al*. 2014 [60]	Rachi, Jharkhand	1382	1138	82.34	244	17.66
12	Manjunath., *et al*. 2014 [49]	Hyderabad, Andhra Pradesh	473	365	77.16	108	22.84
13	Vijayanchali , 2014 [38]	Dindigul, Tamil Nadu	2977	2603	87.43	374	12.57
14	Rengma., *et al*. 2015 [41]	Karbi-Anglong, Assam	826	737	89.22	89	10.78
15	Sharma., *et al*. 2016 [50]	Chandigarh	350	145	41.42	205	58.58
16	Nagendra., *et al*. 2017 [52]	Shivamogga, Karnataka	2000	1367	68.35	633	31.65
17	Karmakar., *et al*. 2018 [53]	Hooghly, West Bengal	510	355	69.60	155	30.40
18	Selvaraj., *et al*. 2018 [61]	Kancheepuram,Tamil Nadu	360	257	71.38	103	28.62
19	Shikha., *et al*. 2019 [54]	Dehradun, Uttarakhand	632	421	66.61	211	33.39
20	Manojan., *et al*. 2019 [55]	Trivandrum, Kerala	350	260	74.28	90	25.72
21	Bindhu., *et al*. 2019 [56]	Trivandrum, Kerala	300	178	59.33	122	40.67
22	Ganie., *et al*. 2021 [46]	Kashmir, Jammu and Kashmir	4038	3206	79.39	832	20.61
23	Thanglen., *et al*. 2022 [47]	Manipur	207	183	88.40	24	11.60
		TOTAL	20726	15855	76.49	4871	23.51
[BMI<25 kg/m^2: Underweight + Normal + Overweight / BMI≥25 kg/m^2: Obese)]							

Table 4: Variability of BMI (<25 kg/m^2 and ≥25 kg/m^2) among Asian Indian adults. [According to WHO BMI Cut off (Asian + International)] [Arranged by year of publication].

Prevalence of overweight based on BMI

The prevalence of overweight based on BMI among 15941 Asian Indian adults of 19 studies are mentioned in table-5. Area, community, habitat and age group of each study are mentioned. The prevalence of each study is mentioned with 95% CI and weight of fixed and random effect in percentage. The pooled prevalence (fixed effect) of overweight is 20.41% (95% CI 19.78 to 21.04) with a significant level of heterogeneity among the studies (I^2 = 98.71%, p < 0.0001). Further it is evident from table 5, that highest prevalence of overweight based on BMI was 82.49% (95% CI 77.28 to 86.93), reported by Mungreiphy., *et al*. (2011) [28] among rural tribal people of Ukhrul, Manipur. Similarly lowest

prevalence of overweight based on BMI was 12.05% (95% CI 9.25 to 15.33), reported by Manjunath., *et al*. (2014) [49] among urban people of Hyderabad, Andhra Pradesh. The result of Egger's test for the funnel plot was statistically significant for the presence of publication bias (p = 0.002). The result of Begg's test was also statistically significant for the presence of publication bias (p = 0.035). Figure 2 and figure 3 showed the table 5 outcomes through funnel plot and forest plot respectively.

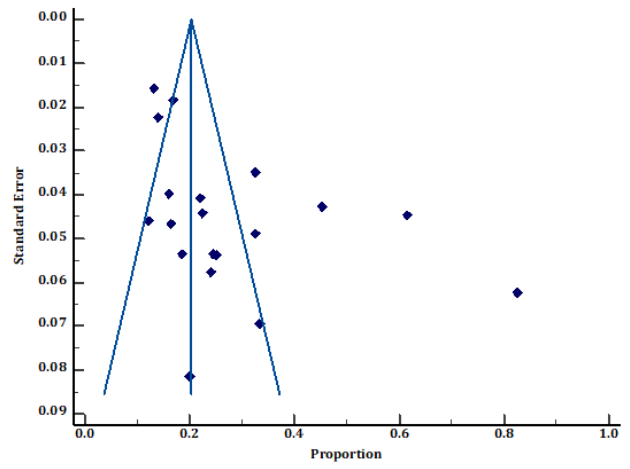

Figure 2: Distribution of studies included in OVERWEIGHT based on BMI analysis among Asian Indian adults in the funnel graph.

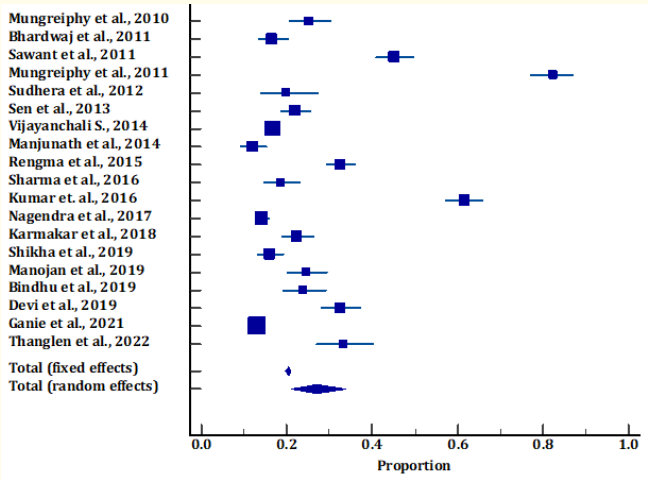

Figure 3: Forest plot for the prevalence of OVERWEIGHT based on BMI among Asian Indian adults.

Prevalence of obesity based on BMI

The prevalence of obesity based on BMI among 15941 Asian Indian adults of 19 studies is mentioned in table 6. Area, community, habitat and age group of each study are mentioned. The prevalence of each study is mentioned with 95% CI and weight of fixed and random effect in percentage. The pooled prevalence (fixed effect) of obesity is 23.54% (95% CI 22.88 to 24.21) with a significant level of heterogeneity among the studies (I^2 = 98.80%, p < 0.0001). Further it is evident from table-6, that highest prevalence of obesity based on BMI was 67.46% (95% CI 62.74 to 71.93), reported by Devi., *et al*. (2019) [45] from Delhi. Similarly lowest prevalence of obesity based on BMI was 2.02% (95% CI 0.81 to 4.12), reported by Mungreiphy and Kapoor (2010) [27] among rural people of Ukhrul, Manipur. The result of Egger's test for the funnel plot was statistically non-significant for the presence of publication bias (p = 0.189). The result of Begg's test was also statistically non-significant for the presence of publication bias (p = 0.725). Figure 4 and figure 5 shows the table-6 outcomes through funnel plot and forest plot respectively.

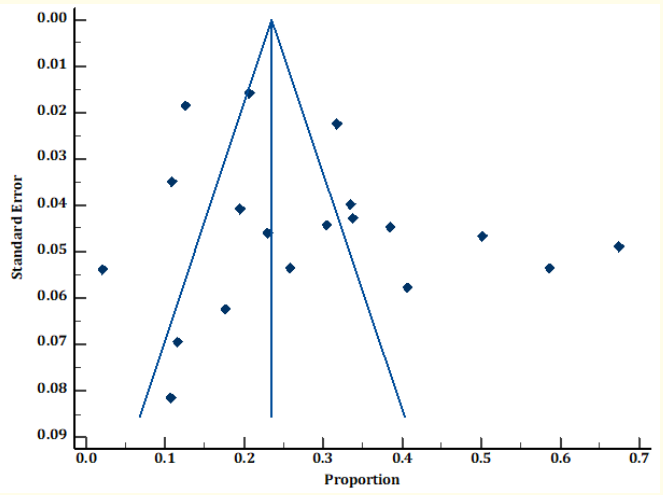

Figure 4: Distribution of studies included in OBESITY based on BMI analysis among Asian Indian adults in the funnel graph.

SL	Name of the Study	Region	Area of the Study	Community	Habitat	Age [Group/ Mean ± SD]	n	No. of Obese	Prevalence % Fixed	95% CI Random	Weight (%)	
1	Mungreiphy., *et al*. 2010 [27]	North Eastern	Ukhrul, Manipur	Tribal	Rural	20-70	346	7	2.02	0.81 to 4.12	2.17	5.24
2	Bhardwaj., *et al*. 2011 [30]	Northern	New Delhi, Delhi	Non-Tribal	Urban	42.9±11.7	459	230	50.10	45.43 to 54.77	2.88	5.27
3	Sawant., *et al*. 2011 [48]	Western	Mumbai, Maharashtra	Non-Tribal	Urban	54.28±13.89	548	185	33.75	29.80 to 37.88	3.44	5.29
4	Mungreiphy., *et al*. 2011 [28]	North Eastern	Ukhrul, Manipur	Tribal	Rural	20-70	257	45	17.51	13.06 to 22.71	1.62	5.19
5	Sudhera., *et al*. 2012 [31]	Northern	Amritsar, Punjab	Non-Tribal	Urban	18-25	150	16	10.66	6.22 to 16.74	0.95	5.07
6	Sen., *et al*. 2013 [32]	Eastern	Jalpaiguri, West Bengal	Non-Tribal	Urban	20-60	600	117	19.50	16.40 to 22.90	3.77	5.30
7	Vijayanchali , 2014 [38]	Southern	Dindigul, Tamil Nadu	Non-Tribal	Rural	18-55	2977	374	12.56	11.39 to 13.80	18.66	5.36
8	Manjunath., *et al*. 2014 [49]	Southern	Hyderabad, Andhra Pradesh	Non-Tribal	Urban	18-25	473	108	22.83	19.12 to 26.88	2.97	5.28
9	Rengma., *et al*. 2015 [41]	North Eastern	Karbi-Anglong, Assam	Tribal	Rural and Urban	20-49	826	89	10.77	8.74 to 13.09	5.18	5.32
10	Sharma., *et al*. 2016 [50]	Northern	Chandigarh	Non-Tribal	Urban	45-55	350	205	58.57	53.21 to 63.78	2.20	5.24
11	Kumar., *et al*. 2016 [51]	Eastern	Rachi, Jharkhand	Non-Tribal	Rural	≥ 20	500	192	38.40	34.11 to 42.82	3.14	5.28
12	Nagendra., *et al*. 2017 [52]	Southern	Shivamogga, Karnataka	Non-Tribal	Urban	15-64	2000	633	31.65	29.61 to 33.73	12.54	5.35
13	Karmakar., *et al*. 2018 [53]	Eastern	Hooghly, West Bengal	Non-Tribal	Rural	≥ 20	510	155	30.39	26.42 to 34.58	3.20	5.28

14	Shikha., *et al*. 2019 [54]	North-ern	Dehradun, Uttarakhand	Non-Tribal	Rural and Urban	20-60	632	211	33.38	29.71 to 37.21	3.97	5.30
15	Manojan., *et al*. 2019 [55]	South-ern	Trivandrum, Kerala	Non-Tribal	Urban	18-24	350	90	25.71	21.21 to 30.63	2.20	5.24
16	Bindhu., *et al*. 2019 [56]	South-ern	Trivandrum, Kerala	Non-Tribal	Rural	≥ 18	300	122	40.66	35.05 to 46.46	1.89	5.22
17	Devi., *et al*. 2019 [45]	North-ern	Delhi	Non-Tribal	Urban	20-55	418	282	67.46	62.74 to 71.93	2.63	5.26
18	Ganie., *et al*. 2021 [46]	North-ern	Kashmir, Jammu and Kashmir	Tribal	Rural	≥ 20	4038	832	20.60	19.36 to 21.88	25.31	5.37
19	Thanglen., *et al*. 2022 [47]	North East-ern	Manipur	Tribal	Rural	20-79	207	24	11.59	7.57 to 16.75	1.30	5.15
					Total (fixed effects)		15941	3917	23.54	22.88 to 24.21	100	100
	Total (random effects)					26.77	20.48 to 33.59	100	100			
	Test for heterogeneity			Publication bias								
	Significance level	P < 0.0001		Egger's test		Begg's test						
	I^2 (inconsistency)	98.80%		Intercept	6.11	Kend-all's Tau	0.06					
	95% CI for I^2	98.57 to 99.00		95% CI	-3.33 to 15.56	Signifi-cance lev-el	P = 0.7257					
				Signifi-cance level	P = 0.1899							

Table 6: Prevalence of OBESITY based on BMI among Asian Indian adults [According to WHO BMI Cut off (Asian)].

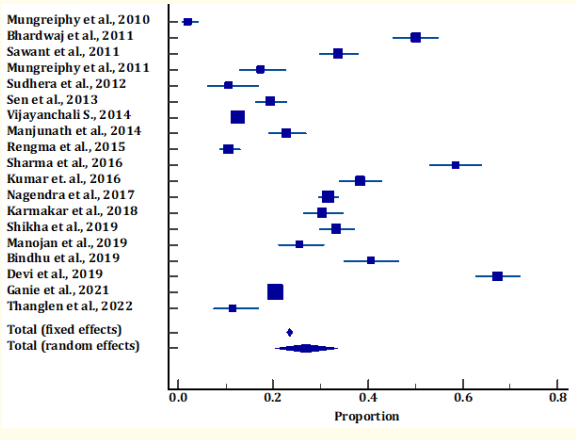

Figure 5: Forest plot for the prevalence of OBESITY based on BMI among Asian Indian adults.

Variability of WC

Variability of WC (mean ± SD) among Asian Indian adults reported by 12 studies from 2006 to 2019 is mentioned in table-7. The total sample size of selected studies is 10219 which constitute 4033 males and 6186 females. The combined mean of WC for males and females are 89.33 ± 12.71 cm and 85.48 ± 12.74 cm respectively. Further it is evident from table 7, that highest mean WC for male was 106.65 ± 7.4 cm, reported by Kaur., *et al*. (2013) [34] from Amritsar, Punjab and the highest mean WC for female was 96.25 ± 11.1 cm, reported by Kaur., *et al*. (2013) [33] from urban area of Punjab. Similarly lowest mean WC for male and female was 78.9 ± 11 cm and 74.4 ± 11.1 cm respectively, both reported by Midha., *et al*. (2014) [40] from Kanpur, Uttar Pradesh.

Summary of findings

The summary of findings and subgroup analysis of studies reporting prevalence of overweight and obesity based on BMI among Asian Indian adults are mentioned in Table 8. The pooled prevalence (fixed effect) and inconsistency value (I^2) with 95% CI along with number of pooled studies with sample size are mentioned on the basis of sex, geographical region, habitat, ethnicity and year of publication. In case of sex variation, adult males show the highest prevalence of overweight based on BMI is 22.47% than adult females (20.69%) but, adult females show the highest prevalence of obesity based on BMI is 26.08% than adult females (20.67%). Beside this, North Eastern regions show highest prevalence (39.02%) of overweight and Northern regions show highest prevalence of obesity (28.61%) among regions. The Western and Central regions show no results due to inadequacy or unavailability of studies. Urban adults show slightly high prevalence of overweight (20.15%) and obesity (34.39%) based on BMI than rural adults, 19.86% for overweight and 18.46% for obesity respectively. Similarly, non-tribal adults show slightly high prevalence of overweight (20.85%) and high prevalence of obesity (27.44%) based on BMI than tribal overweight (19.62%) and obese (17.03%) adults. The pooled prevalence of 5 studies from 2010-12 show the highest prevalence of overweight among adults of 34.48%, where the pooled prevalence of 4 studies from 2016-18 show the highest prevalence of obesity among adults of 35.15%. All tests for heterogeneity trend are statistically significant ($p < 0.0001$).

Parameters	Number of Studies pooled (with sample size)	Pooled prevalence of Overweight (95% CI)	I^2 (inconsistency) (95% CI for I^2)	Pooled prevalence of Obesity (95% CI)	I^2 (inconsistency) (95% CI for I^2)	P for heterogeneity trend
SEX						
Male	11 (n = 4831)	22.47% (21.29 to 23.66)	98.71% (98.36 to 98.99)	20.67% (19.54 to 21.84)	97.84% (97.12 to 98.38)	P < 0.0001
Female	14 (n = 5722)	20.69% (19.65 to 21.76)	88.51% (82.47 to 92.47)	26.08% (24.95 to 27.24)	98.69% (98.37 to 98.94)	P < 0.0001
GEOGRAPHICAL REGION						
Northern	6 (n = 6047)	15.32% (14.43 to 16.26)	94.58% (90.69 to 96.84)	28.61% (27.46 to 29.75)	99.25% (99.00 to 99.44)	P < 0.0001
Eastern	3 (n = 1610)	33.62% (31.31 to 35.98)	99.15% (98.63 to 99.47)	28.52% (26.33 to 30.79)	95.98% (91.37 to 98.13)	P < 0.0001
North Eastern	4 (n = 1636)	39.02% (36.65 to 41.43)	98.89% (98.30 to 99.27)	9.47% (8.09 to 10.99)	94.62% (89.30 to 97.30)	P < 0.0001
Southern	5 (n = 6100)	16.29% (15.37 to 17.24)	90.45% (80.64 to 95.29)	21.01% (19.99 to 22.05)	98.80% (98.26 to 99.17)	P < 0.0001
HABITAT						
Rural	8 (n = 9135)	19.86% (19.05 to 20.70)	99.33% (99.15 to 99.47)	18.46% (17.67 to 19.27)	98.39% (97.80 to 98.82)	P < 0.0001
Urban	9 (n = 5348)	20.15% (19.08 to 21.25)	97.16% (95.97 to 98.00)	34.39% (33.12 to 35.68)	98.37% (97.81 to 98.78)	P < 0.0001
ETHNICITY						

Tribal	5 (n = 5674)	19.62% (18.59 to 20.67)	99.43% (99.23 to 99.57)	17.03% (16.06 to 18.04)	97.69% (96.32 to 98.54)	P < 0.0001
Non Tribal	14 (n = 10267)	20.85% (20.06 to 21.64)	98.12% (97.61 to 98.53)	27.44% (26.58 to 28.31)	98.82% (98.55 to 99.04)	P < 0.0001
YEAR OF PUBLICATION						
2010-2012	5 (n = 1760)	36.48% (34.23 to 38.78)	99% (98.58 to 99.30)	24.61% (22.61 to 26.68)	98.93% (98.46 to 99.25)	P < 0.0001
2013-2015	4 (n = 4876)	19.41% (18.31 to 20.55)	97.27% (95.22 to 98.44)	13.95% (12.99 to 14.96)	94.18% (88.23 to 97.12)	P < 0.0001
2016-2018	4 (n = 3360)	21.70% (20.31 to 23.13)	99.31% (99.01 to 99.51)	35.15% (33.54 to 36.79)	96.91% (94.47 to 98.27)	P < 0.0001
2019-2022	6 (n = 5945)	16.38% (15.44 to 17.34)	96.74% (94.83 to 97.95)	25.72% (24.61 to 26.85)	98.88% (98.45 to 99.19)	P < 0.0001

Table 8: Summary of findings and subgroup analysis of studies reporting prevalence of overweight and obesity based on BMI among Asian Indian adults.

In Table 9, meta-regression was performed to explore the heterogeneity between the studies reporting prevalence of obesity based on BMI among Asian Indian adults. The value of R^2, residual SD and F-Ratio are mentioned on the basis of geographical region, habitat and ethnicity. All tests are statistically non-significant. The Western and Central regions show no results due to inadequacy or unavailability of studies. Northern, Rural and Tribal from geographical region, habitat and ethnicity respectively are considered as reference value for meta-regression (Value: 1).

Parameters	R^2	Residual SD	F-ratio	P Value
GEOGRAPHICAL REGION				
Northern	Ref.			
Eastern	0.507	25.37	1.031	0.4951
North Eastern	0.527	17.78	2.228	0.2741
Southern	0.232	22.75	0.910	0.4105
HABITAT				
Rural	Ref.			
Urban	0.186	13.31	1.372	0.2858
ETHNICITY				
Tribal	Ref.			
Non Tribal	0.248	7.15	0.989	0.3931

Table 9: Meta regression performed to explore the heterogeneity between the studies reporting prevalence of OBESITY based on BMI among Asian Indian adults [According to WHO BMI cut off (Asian)].

Discussion

This systematic review and meta-analysis was set out to determine the pooled prevalence of overweight and obesity among Asian Indian adults. The pooled prevalence of overweight and obesity among Indian adults on the basis of BMI is 20.41% and 23.54% respectively. While, according to National Family Health Survey-5, the prevalence of overweight/obesity among adult (aged 15-49 Years) male and female based on BMI (≥25.0 kg/m^2) were 22.9% and 24% respectively [16]. In this meta-analysis, 41.64% adults have had mean BMI≥23 kg/m^2, which is categorized by WHO as an overweight for Asian populations. In case of regional variations of prevalence of overweight and obesity in India, people of North eastern regions showed highest prevalence of overweight (39.02%) and Northern regions showed lowest prevalence of overweight (15.32%). But interestingly, Northern regions showed highest prevalence of obesity (28.61%) and North eastern regions showed lowest prevalence of obesity (9.47%) among adults. The people of North-East are short in stature as compared to the Northern region. Several studies demonstrated that there is a correlation between BMI and Cormic index (CI) (ratio of stature and sitting height) [22,62,63]. Norgan (1994) [62] revealed that BMI will be lower for individuals who have a higher sitting height. It indicates there is an inverse relationship between BMI and CI. But, Adak., *et al*. (2006) [22] have showed positive but statistically insignificant correlation between CI and BMI. Further, according to Khongsdier (2001) [64], BMI is largely not dependent on ethnic or genetic variation. BMI correlates with CI, which may be influenced by genetic and environmental factors. Hence higher prevalence of overweight among north-eastern population can also be explained in that context. The results of this meta-analysis may vary if studies are available from western and central regions.

In case of habitat variation, urban adults showed high prevalence for both overweight (20.15%) and obesity (34.39%) compared to their rural counterparts. Several studies have revealed that faulty food habits and sedentary lifestyles are main reasons of it. Further, tribal people from rural areas, showed low prevalence for both overweight and obesity compared to non-tribal counterpart, which again proves the ill impact of urban lifestyles on nutritional health.

Limitations of the Study

The articles were searched from electronic databases, such as PubMed, PMC, Google Scholar and Scopus. Articles from other electronic databases and print databases, Grey material, thesis, dissertations were not considered for present systematic review and meta-analysis. The duration of search was restricted from January 2000 to June 2022. Articles published before 2000 were not included in this study. The data search was done during May 15 to June 30, 2022. This review is restricted only on Asian Indian adult population. The articles published only in English Language were included for the analysis.

Conclusion

This systematic review and meta-analysis concluded that the prevalence rate of overweight and obesity among Indian adults of both sexes is increasing day by day. Urban people are more prone of being overweight and obese as compared to their rural counterparts. Prevention should begin at an early age, when modification in lifestyle can reduce the incidence of overweight and obesity and associated other diseases. Therefore, there is a need for an effective preventive strategy and health awareness programs at local and national level, targeting the affected people to encourage and improve their unhealthy lifestyle.

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